

High Power Photodetectors for Space Communications Applications

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Abstract

High power photodetectors in coplanar waveguide and distributed traveling-wave structures have been under development for communications applications. The distributed photodetectors demonstrated 70% efficiency with a linear response upto 25 mW of optical power input.

Summary

Future space-borne communications systems require advanced photonic components and concepts to provide improved link performance but at smaller size, weight and cost. The goal is to achieve two orders of magnitude improvement over the current state-of-the-art in the link loss, dynamic range, and receiver tracking threshold level. The applications include high performance radio frequency (RF)/Optical Signal Distribution System for phased array antennas, onboard signal processing, antenna remoting, and optical communications systems. The approach is to develop dual use high payoff components in collaboration with industry and university, demonstrate performance advantages, and identify potential commercial and space system insertion applications. This paper reports on the recent developments on a coplanar waveguide photodetector developed at Microdevices Laboratory (MDL) at JPL, and a distributed photodetector developed at University of California at Los Angeles (UCLA).

High Saturation Power Coplanar Waveguide Photodetector:

The performance of planar p-i-n photodiodes for high speed and high power RF optical links is limited by their bandwidth-efficiency trade off. Waveguide p-i-n photodetectors can overcome this trade off, but careful wafer design and device fabrication issues must be considered to obtain both high speed and high power handling capability. We have fabricated waveguide p-i-n photodetectors in the InP based material system using a lattice matched InGaAs absorbing region and InGaAsP and InAlGaAs cladding regions. The use of different cladding regions has been explored to determine the optical power handling properties of varying band offsets for photocarriers escaping the absorbing region. Coplanar transmission line contacts are utilized to reduce parasitic for high speed operation and device geometry and depletion width have been designed to push RC and transit time limitations over 40 GHz.

Initial results on InGaAs/InGaAsP devices have shown typical dark currents of 1.0 nA at -5 V and capacitances of 95 fF for a 250 μm^2 device with 10 μm wide waveguide. A responsivity of 0.13 A/W was measured for the device using 1.3 μm incident light from a cleaved single mode fiber. The measured responsivity is uniform for applied biases from +0.25 V to -5 V, which indicates a significant built-in field due to the doping of the p and n regions and implies that these devices can be operated with a relatively low bias voltage. A linear increase in photocurrent versus incident optical power was observed for photocurrents up to 7 mA.

Additional measurements on saturation and frequency response characteristics are planned with lensed fiber to increase the coupling efficiency.

Ultrafast High Power Distributed Photodetector:

The high power distributed photodetector shown in Fig. 1 consists of 27 p-i-n photodiodes, each with dimensions of $3\mu\text{m} \times 3\mu\text{m}$, serially connected by an optical waveguide. The photocurrents are collected by a coplanar waveguide with 50Ω impedance and velocity matched to that of the optical waveguide. The velocity matching is achieved by the periodic capacitive loading of the photodiodes. The optical waveguide consists of AlGaAs cladding and $\text{Al}_{0.1}\text{Ga}_{0.9}\text{As}/\text{GaAs}/\text{Al}_{0.1}\text{Ga}_{0.9}\text{As}$ large-optical-cavity (LOC) core layers. The LOC core is designed to further reduce the optical confinement factor of the optical waveguide and increase the optical saturation power level. The distributed photodetector is fabricated on semi-insulating GaAs substrate with multiple level mesa for electrical contacts to p and n regions. Ion implantation is employed to isolate individual diodes. The photodiodes are biased at -2.5 V through an external bias T for photocurrent measurement. Linear response is observed for photocurrents up to 10 mA as shown in Fig. 2. The highest optical power is limited by catastrophic damage of the photodetector facet. With antireflection coating and passivation of the facet, higher optical power can be expected. The detector currently has pulse response of 50 ps. Higher bandwidth can be obtained by improving the excessive p-contact resistance in our current devices.

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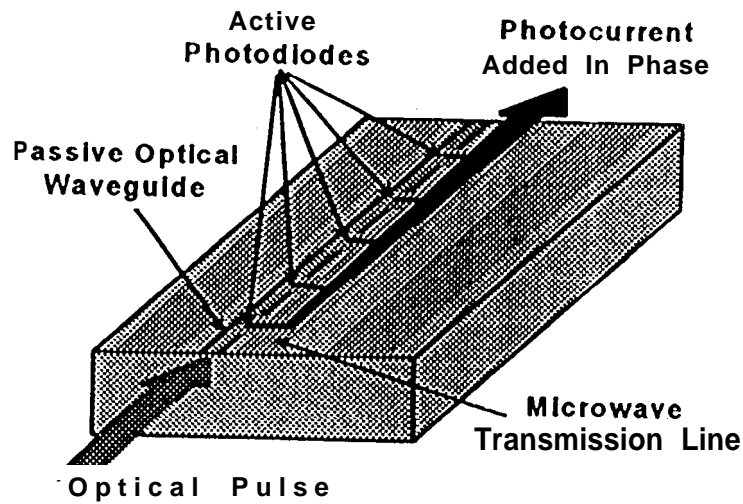


Fig. 1: Schematic diagram of the high power distributed photodetector.

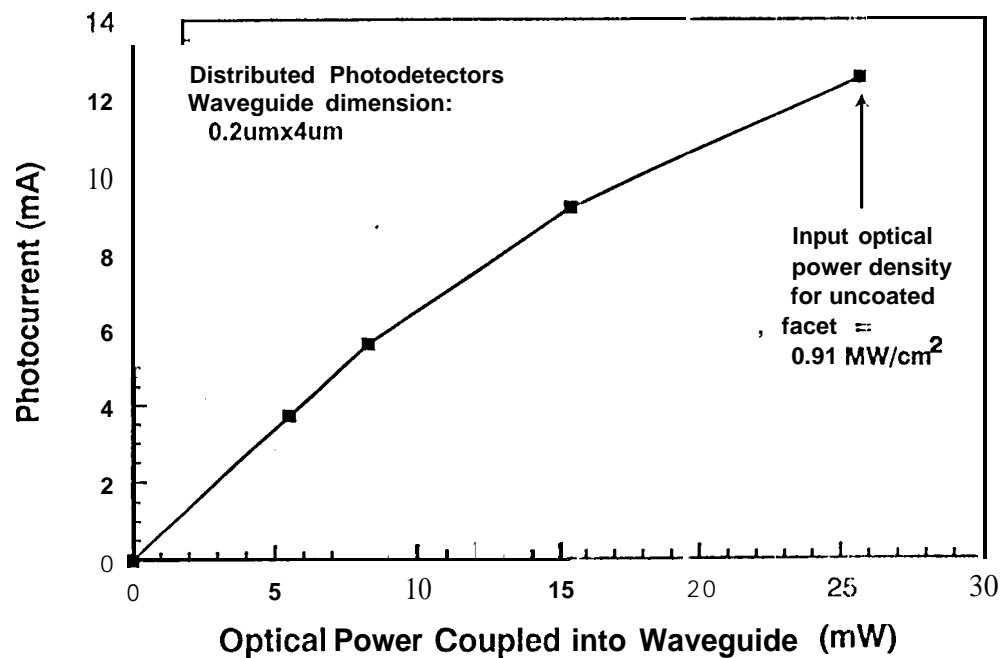


Fig.2: Measured photocurrent versus optical power coupled into waveguide for a distributed photodetector with 27 active photodiodes.